TITLE: ECCS SYSTEMS	AUTHOR: T.L. BELL
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1.0 Training Aids
- 1.1 Transparency Package - R306P-20
- 1.2 Lesson Module #20

2.0 References
- 2.1 B&W Systems Manual - Chapter 5.0
- 2.2 ECCS Evaluation of B&W's 205 FA NSS - Rev 2 (BAW - 10102)
- 2.3 B&W's ECCS Evaluation Model Rev 3 (BAW - 10104)
- 2.4 B&W System Description - DHR (BWNP - 200004)

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3.0 Objectives

3.1 Describe how the decay heat removal system is used to remove decay heat from the core during the later stages of plant cooldown.

3.2 State the source of cooling water to the DHR heat exchangers.

3.3 Explain what a cavating venturi is and why they are used in the emergency core cooling systems.

3.4 List two auxiliary functions performed by the Dechay Heat Removal System.

3.5 Explain the changes involved in converting the makeup and purification system into a high-pressure injection system.

3.6 List tow accidents or malfunctions for which the high-pressure injection system is designed to provide core cooling.

3.7 Explain fht function of the core flooding system.

3.8 Define the following terms:

3.8.1 LOCA

3.8.2 Blowdown Phase

3.8.3 Injection Phase

3.8.4 Recirculation Phase

3.9 Explain the integrated operation of the emergency core cooling systems for the conditions listed in 8.0 above.

4.0 PRESENTATION

4.1 Fission Product Production

4.1.1 7.92 pounds of fission products are produced each day when the unit is operated at 100%.

4.1.2 NRC exists to protect the public from dangers of fission products.

4.2 Fission Product Barriers

4.2.1 Fuel Clad

4.2.1.1 .048 inches thick.

4.2.1.2 Cladding damage minimized by 10CFR50.46 limits.

4.2.2 RCS Pressure Boundry

4.2.2.1 >2" pipe thickness.

4.2.2.2 >8" reactor vessel thickness.

4.2.2.3 Failure requires ECCS.

4.2.2.4 Break Definitions

4.2.2.4.1 Small Break - < 0.5 ft squared

4.2.2.4.2 Large Break - > 0.5 ft squared

4.2.2.5 Small and large breaks differ radically in heat transfer and are analyzed differently.

4.2.2.6 0.5 ft squared break is analyzed both as a small and a large break.

4.2.3 Reactor Building Barrier - Seperate lecture

4.3 LOCA Description

4.3.1 Definition - a leak in excess of normal makeup (greater than ~ 200 GPM)

4.3.2 Large LOCA
- 4.3.2.1 Rupture occurs
- 4.3.2.2 Pressure forces fluid through the break
- 4.3.2.3 Automatic Reactor Trip
- 4.3.2.4 Reduction in pressure allows coolant to flash to steam.

4.3.3 Blowdown Phase
- 4.3.3.1 Definition - the dropping of the potential energy of the RCS to a level equal to its immediate surroundings. (Reactor Building)
- 4.3.3.2 DNBR occurs quickly.
- 4.3.3.3 Cladding temperatures increase by 600 to 800 degrees - cooling is by film boiling.
- 4.3.3.4 During the last portion of the blowdown phase, cooling is by steam convection.

4.3.4 Heatup Phase
- 4.3.4.1 Definition - a finite period of time is required for ECCS equipment to start and the core to refill
- 4.3.4.2 Decay Heat continues core heatup
- 4.3.4.3 1.2 times the ANS decay heat curve is assummed for analysis.
- 4.3.4.4 Cladding can rupture and release fission products to the reactor building atmosphere.

4.3.5 Reflood Phase
- 4.3.5.1 ECCS Fluid reaches bottom of vessel
- 4.3.5.2 During the injection phase, the fluid is supplied by the BWST.

4.3.6 Recirculation Phase
- 4.3.6.1 Long Term Core Cooling
- 4.3.6.2 ECCS pumps supplied with fluid from RB Sump.

4.4 ECCS Requirements
- 4.4.1 GDC 35 - Redundancy
- 4.4.2 GDC 17 - Emergency Power Supplies
- 4.4.3 GDC 20 - Emergency Powered Actuation Signals

4.5 B&W ECCS Systems
- 4.5.1 Three Systems
- 4.5.2 Active Systems
  - 4.5.2.1 High Pressure Injection
  - 4.5.2.2 Low Pressure Injection
  - 4.5.2.3 Both systems are used in the injection and recirculation phases.
- 4.5.3 Passive System - Core Flood Tanks.

4.6 Decay Heat Removal/Low Pressure Injection System
- 4.6.1 System Functions
  - 4.6.1.1 Low pressure - high volume ECCS during the the injection phase
  - 4.6.1.2 Low pressure - high volume ECCS during the recirculation.
  - 4.6.1.3 Normal plant cooldown from 305 degrees and 400 psig to cold shutdown conditions
  - 4.6.1.4 Pressurizer Auxiliary Spray
  - 4.6.1.5 Purification during CSD via MU&P interface
  - 4.6.1.6 Backup Spent Fuel Pool Cooling

4.6.1.7 Filling or draining of Refueling canal
4.6.1.8 DHR during refueling.

4.6.2 Component Descriptions

4.6.2.1 Decay Heat Removal Pumps
4.6.2.1.1 Powered from vital AC busses
4.6.2.1.2 Single stage centrifugal pumps
4.6.2.1.3 ECCS flow of 5125 gpm at 150 psig
4.6.2.1.4 125 gpm recirc flow
4.6.2.1.5 Mechanical seals are installed on the pumps.

4.6.2.2 Decay Heat Removal Coolers
4.6.2.2.1 Function to reduce RB sump temp during recirculation phase
4.6.2.2.2 Function to reduce RCS temp during a normal cooldown.
4.6.2.2.3 Designed to reduce temperature from 305 degrees to 140 degrees in 14 hrs assuming that DHR is placed in service 6 hrs following a shutdown.

4.6.2.3 DHR Cooler decay heat load assumptions- designed to maintain < 140 degrees assuming the following:
4.6.2.3.1 1/3 core after 292 days of operation
4.6.2.3.2 1/3 core after 584 days of operation
4.6.2.3.3 1/3 core after 1044 days of operation
4.6.2.3.4 Initial power level of 3906 MWt.

4.6.2.4 The DHR coolers are cooled by the Shutdown Cooling Water system - Safety Related, closed loop system that is cooled by emergency service water.

4.6.2.5 Cavitating Venturis
4.6.2.5.1 Function to limit LPI flow in the event of a LPI header break
4.6.2.5.2 Will limit flow to < 5800 gpm which is less than pump runout flow of 6500 gpm
4.6.2.5.3 As flow increases, pressure drop increases
4.6.2.5.4 At high flow rates, cavitation occurs which limits flow.

4.6.3 Normal DHR Operations

4.6.3.1 Basic Flowpath
4.6.3.1.1 From RCS hot leg
4.6.3.1.2 DHR Pump
4.6.3.1.3 DHR Cooler
4.6.3.1.4 Into vessel via LPI/CFT nozzles
4.6.3.1.5 flows up through fuel to RCS hot leg

4.6.3.2 DHR Suction Valves
4.6.3.2.1 Interlocked closed at 400 psig
4.6.3.2.2 Interlock supplied by ESFAS and ECI instrumentation
4.6.3.2.3 Purpose - to protect DHR piping from overpressure.

4.6.3.3 DHR Suction Reliefs
- 4.6.3.3.1 Setpoint - 435 psig
- 4.6.3.3.2 Capacity - 2100 gpm
- 4.6.3.3.3 Designed to prevent overpressurization during:
  - 4.6.3.3.3.1 Loss of DHR cooling
  - 4.6.3.3.3.2 energization of all pzr htrs
  - 4.6.3.3.3.3 maximum makeup flow (MU valve fails open)
  - 4.6.3.3.3.4 Inadvertant HPI (limiting)

4.6.3.4 Cooler Outlet/Bypass valves
- 4.6.3.4.1 Valves used in combinitation to control cooldown
- 4.6.3.4.2 Temp too high - open outlet to increase flow thru cooler. Close bypass to control flow @ 5000 gpm
- 4.6.3.4.3 Temp too low - Open bypass. Close outlet to control flow @ 5000 gpm

4.6.3.5 Cavitating Venturis
- 4.6.3.5.1 Cross - connect lines closed
- 4.6.3.5.2 Bypass around "in-line" venturi opened (NOT SHOWN ON DRAWING)

4.6.3.6 Flow returns to vessel via LPI/CFT lines.

4.6.3.7 Purification flow path
- 4.6.3.7.1 Supplies water from DHR pump discharge to MU&P upstream of prefilter
- 4.6.3.7.2 Temp must be less than 145 degrees (ion exchanger limit)
- 4.6.3.7.3 Flow is returned to DHR pump suction from MUT inlet line.

4.6.3.8 Auxiliary Spray Flowpath
- 4.6.3.8.1 May be supplied from either DHR system
- 4.6.3.8.2 Must maintain pzr cooldown rates
- 4.6.3.8.3 Cannot be used until $<$ 400 psig
- 4.6.3.8.4 Natural circ cooldowns from Mode 3 require an alternate method of depressurization

4.6.3.9 Fill/Drain of fuel transfer canal
- 4.6.3.9.1 Head detensioned
- 4.6.3.9.2 One DHR system is aligned to BWST
- 4.6.3.9.3 Flow out through open vessel to canal
- 4.6.3.9.4 Head is lifted as canal fills
- 4.6.3.9.5 Draining is accomplished by directing DHR pump discharge back to BWST. (CONNECTION NOT SHOWN ON SIMPLIFIED DRAWING)

4.6.3.10 Refueling Operations
- 4.6.3.10.1 Same alignment as when in normal DHR
- 4.6.3.10.2 Flow may be stopped for an hour if fuel is being handled in the vicinity of hot leg nozzle.

4.6.3.11 Backup Spent Fuel Cooling
4.6.3.11.1 Suction from SF Pool
4.6.3.11.2 Connection to SF pool on DHR discharge.
4.6.3.11.3 CONNECTIONS NOT SHOWN ON SIMPLIFIED DRAWING
4.6.4 LPI Operations - Injection Phase
4.6.4.1 Alignment
4.6.4.1.1 Performed during heatup after RCPs are started
4.6.4.1.2 Hot Leg Suctions are closed
4.6.4.1.3 Manual valves from BWST/Sump are opened
4.6.4.1.4 In-line cavitating venturi bypasses are closed.
4.6.4.1.5 Cross-connection cavitating venturis are opened.
4.6.4.1.6 Cooler outlet is 100% open
4.6.4.1.7 Cooler bypass is closed.
4.6.4.2 LPI Start Signals
4.6.4.2.1 ESFAS Channels 1A/1B
4.6.4.2.2 Low RCS Pressure, low OTSG Pressure, High RB Pressure
4.6.4.2.3 ESFAS signal starts pumps, opens LPI MOVs
4.6.4.3 Flowpath - RCS Press > 200 psig
4.6.4.3.1 Flow through cooler back to pump suction via orficed recirc line
4.6.4.3.2 Shutdown Cooling Water is also started by ESFAS 1A/1B.
4.6.4.4 Flowpath - RCS Press < 200 psig
4.6.4.4.1 From BWST
4.6.4.4.2 Through LPI pump
4.6.4.4.3 Through DHR Cooler
4.6.4.4.4 Into vessel via injection nozzles
4.6.5 LPI Operation Recirculation Phase
4.6.5.1 Actuation Signals
4.6.5.1.1 Low BWST Level
4.6.5.1.2 Must also have a HPI signal
4.6.5.2 Flowpath Changes
4.6.5.2.1 Sump suctions open
* 4.6.5.2.2 BWST outlets closed by operator
4.6.5.2.3 LPI/HPI (piggy back) valves opened operator
4.6.5.2.4 HPI may be secured if LPI flow > 1500 gpm
4.7 Core Flooding System
4.7.1 General System Description
4.7.1.1 Passive
4.7.1.2 Two tanks
4.7.1.3 Share LPI vessel penetration
4.7.1.4 600 psig nitrogen forces water into RCS during LOCA
4.7.2 Tank Description
4.7.2.1 Volume = 1800 cubic feet.
4.7.2.2 Operating Volume = 1350 cubic feet
4.7.2.3 Design Pressure = 700 psig
4.7.2.4 Operating Pressure = 600 + or - 25 psig
~~4.7.2.5 Boron Concentration = 2270 ppm~~

4.7.3 Tank Outlet Valve
- 4.7.3.1 Will not satisfy single failure criteria
- 4.7.3.2 Opened and locked open above 800 psig
- 4.7.3.3 Operating Bypass per IEEE - 279
- 4.7.3.4 Interlocks/Alarms
  - 4.7.3.4.1 If valve is closed and RCS press > 750 psig, an alarm is sounded in control room
  - 4.7.3.4.2 Valves receive ESFAS 1A/1B signal but should be open
  - 4.7.3.4.3 If valve is open and RCS press < 650 psig, an alarm is sounded in control room

4.7.4 Indications
- 4.7.4.1 Level
  - 4.7.4.1.1 Two Redundant Transmitters
  - 4.7.4.1.2 Range 0 to 21 ft
  - 4.7.4.1.3 15 ft is normal level
- 4.7.4.2 Pressure
  - 4.7.4.2.1 Two redundant Transmitters
  - 4.7.4.2.2 Range 0 to 700 psig
  - 4.7.4.2.3 600 psig is the normal pressure

4.7.5 Miscellaneous Connections
- 4.7.5.1 Relief Valve
  - 4.7.5.1.1 Prevents tank overpressurization
  - 4.7.5.1.2 Setpoint = 700 psig
- 4.7.5.2 Makeup Supply
  - 4.7.5.2.1 Supplied from MU&P
  - 4.7.5.2.2 CFTs are initially borated to ~3500 ppm due to possible dilution from MUT when filling
- 4.7.5.3 Vent Connection
  - 4.7.5.3.1 Used to depressurize tank
  - 4.7.5.3.2 May be used to lower tank press during cooldowns
- 4.7.5.4 Sample Connection

4.8 High Pressure Injection System
- 4.8.1 Functions to provide core cooling for Small Break LOCAs.
- 4.8.2 Provides high pressure - low volume ECCS flow
- 4.8.3 Small Breaks
  - 4.8.3.1 Size ranges from 0.009 square ft to 0.5 square ft.
  - 4.8.3.2 <0.009 is within capacity of makeup system
  - 4.8.3.3 > 0.5 square ft is a large break
- 4.8.4 Small Break Examples
  - 4.8.4.1 Pressurizer Safety Valve
  - 4.8.4.2 PORV
  - 4.8.4.3 Double ended rupture of a single OTSG tube
  - 4.8.4.4 On small break, clad temperature will not exceed 700 degrees
  - 4.8.4.5 CFTs and LPI may also be actuated

4.8.5 MU&P system Changes during LPI
- 4.8.5.1 Letdown is isolated
- 4.8.5.2 MUT outlet is closed
- 4.8.5.3 Normal Makeup is isolated
- 4.8.5.4 Seal Return is isolated and diverted to RCDT
- 4.8.5.5 Pump recircs close
- 4.8.5.6 BWST Outlets open
- 4.8.5.7 2 HPI pumps start
- 4.8.5.8 HPI MOVs open

4.8.6 HPI Flowpath - Injection Phase
- 4.8.6.1 From BWST
- 4.8.6.2 Through Pumps
- 4.8.6.3 Into cold legs via HPI MOVs

4.8.7 HPI Flowpath - Recirculation Phase
- 4.8.7.1 From LPI pump discharge
- 4.8.7.2 Through Pumps
- 4.8.7.3 Into cold legs via HPI MOVs

4.9 Integrated ECCS Operations

4.9.1 Small Breaks - Slow Depressurization
- 4.9.1.1 HPI flow
- 4.9.1.2 CFT flow
- 4.9.1.3 LPI flow

4.9.2 Small Break Conservatisms
- 4.9.2.1 HPI pump performance is degraded from design performance by 10%
- 4.9.2.2 A break in the cold leg allows 30% of total HPI flow to go out the break - 10CFR46 criteria satisfied.

4.9.3 CFT Nozzle Break
- 4.9.3.1 Purpose of cavitating venturis in LPI
  - 4.9.3.1.1 Break occurs in one of two lines
  - 4.9.3.1.2 Pump in other header is the single active failure
  - 4.9.3.1.3 Without venturis, no LPI flow
- 4.9.3.2 As RCS pressure approaches RB pressure, excessive flow through affected header starts cavitation
- 4.9.3.3 Sufficient core cooling from operable train via crossconnects

4.9.4 Large Break - with offsite power
- 4.9.4.1 HPI
- 4.9.4.2 CFTs
- 4.9.4.3 LPI

4.9.5 Large Break - without offsite power
- 4.9.5.1 CFTs
- 4.9.5.2 HPI
- 4.9.5.3 LPI

4.9.6 Inadvertant ECCS actuation at power
- 4.9.6.1 Rarely occurs
- 4.9.6.2 HPI/LPI pumps start
- 4.9.6.3 HPI pumps into RCS
- 4.9.6.4 Operator must override signals to prevent excessive RCS pressures

4.10 Boron Precipation Prevention

4.10.1 Concerns - boric acid is concentrated into a supersaturated solution as the core boils. The acid comes out of solution and plates out on the fuel assembilies. Plate out insulates fuel assembiles.

4.10.2 Methods of Prevention

4.10.2.1 Reverse ECCS flow through the core to flush system

4.10.2.2 Dump to Sump Connections from Hot Legs

4.10.2.2.1 Bellefonte

4.10.2.2.2 Oconee

4.10.2.3 Align LPI to Pzr Aux Spray

4.10.2.4 Hot Leg Injection

4.10.2.4.1 Route discharge from one LPI pump to other train

4.10.2.4.2 Inject water via normal DHR suction valves

5.0 PRA Insites

5.1 HPI System

5.1.1 Dominant system in increases in core melt frequency

5.1.2 Failures are important in both the injection phase and recirculation phase

5.1.3 Operator errror dominates many of the failure sequences. 177FA plants have manual shiftover to RB sump

5.2 LPI System

5.2.1 Required for long term core cooling

5.2.2 Required for HPI recirculation phase operation

5.3 Small LOCA Sequence

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5.3.1 Break of less than 1.2 inches in diameter

5.3.2 Makeup system is able to maintain enough pressurizer leve to keep htrs energized

5.3.3 RCS pressure never drops to ESFAS setpoint

5.3.4 When MUT empties, failure of MU pump occurs

5.3.5 Operator fails to initiate HPI

5.3.6 No cooling flow through the core

5.4 LOCA Sequence

5.4.1 LOCA

5.4.2 ESFAS signal occurs

5.4.3 Proper operation in injection phase

5.4.4 BWST empties

5.4.5 Operator incorrectly shifts suction to sump

5.4.6 No core cooling

5.5 Intersystem LOCA

5.5.1 Event V - Name comes from WASH-1400 studies that were completed in 1978

5.5.2 Both Check valves leak

5.5.3 LPI MOV is opened

5.5.4 LPI system is overpressurized

5.5.5 LOCA outside of containment

5.5.6 Loss of sump recirculation capability

5.5.7 NO CORE COOLING

6.0 Summary

6.1 Cover Objectives

6.2 Answer Student Questions

6.3 Video Tour of systems when available